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INDUSTRIAL MATURITY DEVELOPMENT INDEX: AN APPROACH FROM TECHNOLOGY-DRIVEN RESOURCES

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ABSTRACT

The need for measurement to identify the development stage of industries is crucial to compete and leverage on the industrial business environment. Most of the development processes in Indonesia is influenced and supported by regulatory practices by the authority, and many development plans were based on capital investment rather than stage by stage development which based on industrial ground capabilities. On the other side, the sustainability of industries can be tracked from the competitiveness of its processes, technical methods, and machines. This will lead to better efficiency of its processes which will affect the cost of the products or services and also improve the industrial performance. This paper tries to: (1) use a perspective where the industrial historical momentum can be seen as a benchmark of development stages and give alternatives to focus on technology-driven resources, (2) adopt simple measurement calculations that can be used for comparing one of the industries to another, and also can be used as a benchmarking stage of a group of industries, (3) explain how product specification was related to technical capabilities and how it can be used as competitiveness measurement.

Keywords: *industrial maturity, competitiveness, sustainability, entrepreneurship, industrial revolution*

INTRODUCTION

The technology already become the main topic in development, this is because of its roles as principal driven innovations and game-changer for competition among industries (Porter 1980; Sharif & Ramanathan 1991), the technology development will not end and will give more significant impact for next future challenges (Timings & Tooley 2001). Even more, in 2016 after the promotion of the fourth industrial revolution in world economic forum, the frontier technology was predicted to influence the entire industry and business sectors in general. The fourth industrial revolution with the latest technology will leverage on how we do things. Nowadays a lot of industrial innovation and industry disruptors shape how people conduct business and industries. In Germany, the fourth industrial revolution is known as Industry 4.0 introduced in 2011. This term initially refers to smart digitalization transformation in the manufacturing industry, which indicates most of the technologies wanted are already tested in manufacturing industries. The future challenges that arise are how to implements the concept in other business sectors and the global value chain of global industries (Drath & Horch 2014; Schwab 2016).

The manufacturing industry is known as processes to produce goods and services in mass-scale used tools and resources, which managed to get optimal results and performance. The optimization activity aided by innovations and an effective-efficient approach. These innovations are known as industrial momentums and this changed the trend in the manufacturing industry. These changes also drive the introduction of new variables to measure industrial performances and product development (Afifi 2011a). Manufacturing management was developed from production management, start by process input and ended by process output. There are differences between them, manufacturing management has a bigger scope than production management, not only on the production process but also on other activity units that support production activities (Indrajit & Pramono 2005).

Like other Southeast Asia countries, Indonesia's national industry development and establishment just begin after WWII. This situation not started neither with establishing nor nationalizing financial companies, but on other real sectors that produce goods and services. The main momentum of Indonesia's industrial development based on technology is recorded by the establishment of IPTN (Industri Pesawat Terbang Nasional) (Sharif 2009). This step of momentum provides the next chapter of the national industrial policies to transform industry manufacture became a world-class industry and increasing SME participation in industrial structure or supply chain (Departemen Perindustrian 2008; Kementerian Perindustrian 2015). With those technology-driven policies, affirmed that the technology approach and gap are identified as one of the main issues of stagnation of industry development nt Organization (Ristekdikti 2017; United Nations Industrial Development Organization 2002).

With more chances of introduction to leverage technology in industry into the next level, researcher convinced this move will bring more opportunities of new industries to grow, either by the industry itself or by industry influence in societies, even though relation between new opportunity and leveraging technology is not yet confirmed a direct relation (Acs & Varga 2005). Most technology innovations in a manufacturing area are shaping other sectors in industries and some of it even embodied in products or services. These influences also will change the perspective of how we deal and organize things with technology adoptions, on how another support technology needs it, and on how we as humans adapt to those changes. On the other side, the backward of innovations will also lead to declining of others that support and interact with it (Suarez-Villa 1989).

INDUSTRIAL CAPABILITIES & COMPETITIVENESS

Capabilities and Business Model Frameworks

The latest research identifies both internal and external factors are influencing the industry's strategic activity and business performance. The external factors are also known as the environment or market (DeSarbo et al. 2005), and internal factors are known as capabilities (Grant 2003). The process input to the output of the business model can be explained by identifying the external environment and internal capabilities, then the strategy can be explored as market strategy and non-market strategy, while the performance itself has financial and non-financial values (Parnell & Brady 2019), as shown in Figure 1.

The strategy can be classified into market strategies and non-market strategies. Non-market strategies are the strategic activity that not administered in market activities, such as attaching top management that has a political advantage, social policy activity, or government meets up that gives benefit to the company. This political non-market strategy is common practices in many countries, and it has proven to give a significant impact on the performance of industries (Okhmatovskiy 2010). Industry circumstances that have political ties with the government benefit the industry performance is present in Indonesia (Apriyani, Ika, & Sarnowo 2019). But interestingly there is research that explains how this situation is different in the UK as a developed market and it indicates that political strategy is one of defensive action rather than an innovative action (Parnell & Brady 2019). Financial in other ways need to be defined as target performance-related or more as initial capital that not yet transform to initial capabilities. Based on Figure 1, we can understand that financial performance is an outcome performance of the industry. By this both policy and financial target, we can see it as a top-down approach to stimulate productivity and performance of the industry.

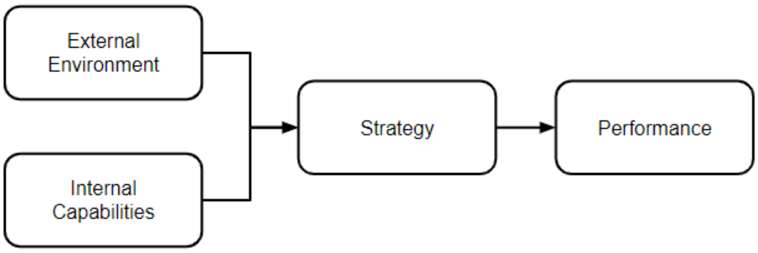


Figure 1. General business model frameworks

Resource-Based View, Technology-Driven Resources and Bottom Up Approach

Resource-based view offers a bottom-up approach since it sees industries as an interactive system that performs well because they rely on respect for their resources to produce quality products (Teece, Pisano & Shuen 1997). Changes and innovations that originated from the optimization of technology-driven resources mostly come from the ground of the work field, despite some of them initiated from top management to introduce a new approach or change direction of industry (Daft 2010).

Technology-driven resources are the most prominent driven capabilities that can change the competition, either as an equalizer, or overtake the competition itself. Any of this technological change is developed from their existing stage of resources and it will change variables of competition (Porter 1985). The gap between one industry with other industries or even developed societies with other non-developed societies is their technological capability for creating wealth (Sharif 2009). To understand how technology-driven resources work, it is easy to understand it into 4 components categories as THIO by Sharif, which are:

1. Technoware – object embodied physical facilities, tools, and artifacts
2. Humanware – person embodied human ingenuity, skills, and talents
3. Infoware – record embodied codified knowledge, facts, and figures
4. Organware – organization embodied operational procedures, steps, and routines

Competitiveness Using Product or Service Specification

With these technology-driven resources, we can try to put our approach on technology view, then lead to another question, how about on our production capacity, machine capability, workers quantity, industrial plants, etc. How we can layout all this variable and direct it in this issue.

Competitive forces by Porter are another strategy approach on how to build competitiveness in the external environment. The threat of substitute products as one of five forces by Porter can be used to understand how it can connect the industry with the market. This can be understood as a product or service specification related. This product or service specification related is something that can associate between the industry's technical capabilities and market needs (Afifi 2011a; Porter 1980). There are so many approaches to identify customer needs and interpreted to the technical specification of product or service at the end of the process. Beyond that is reciprocal communication between customer needs and production capability in which some of it already well establish like DFMA (Design for Manufacturing and Assembly) (Ulrich & Eppinger 2008). The production process in the industry, in general, can be divided into two processes, primary production process, and additional-assembly process. Product and service specifications needed to associate customer needs and production processes in the industry. From product and service specification, we can determine how complex the product, how many sub-products need to produce first and the number of variations of the additional-assembly process needs to be done (Afifi 2011a).

By this, it is important to understand that product and service specifications made by industries are related to the external environment which customer needs. While technology-driven resources related to capabilities, with the assumption the initial financial capital already converted to initial resources. By this, we can show all the assumptions in Figure 2.

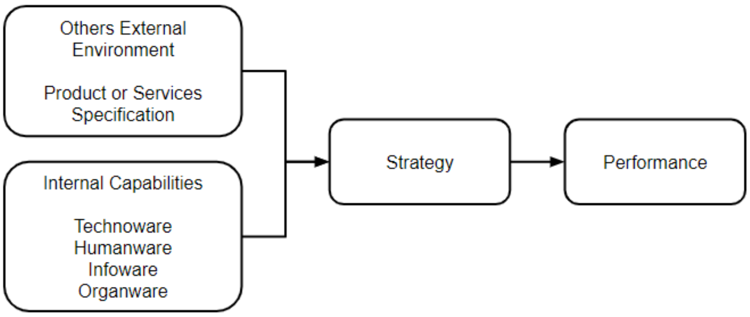


Figure 2. Frameworks for technology-driven resources.

INDUSTRIAL MATURITY DEVELOPMENT INDEX

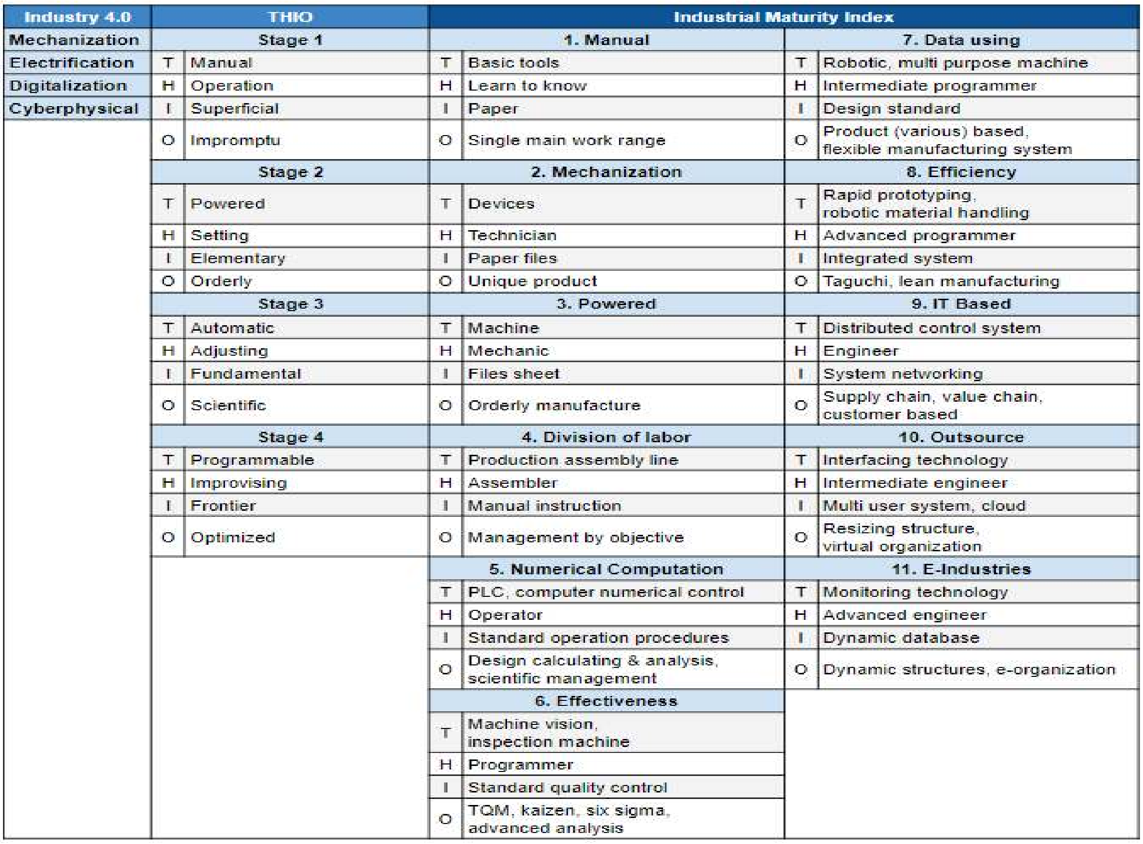
Industrial Maturity & Industry Historical Momentum

Industrial maturity can be assumed as a state where an industrial system can run optimally to reach their quality purposes. To measure industrial maturity to be scaled and compared, we need to observe it with quantitative tools and approaches. It is also important to understand this matured state can be conditioned by locations and circumstances. That is why with every nation or regional character most probably we will see a different matured state, start from generating ideas resulting in products or services.

In general, there are a lot of approaches to describe industrial momentums as innovations, some of them by associating it with the present trend and other by concept condition of the future objective. All innovations cannot be detached from history and milestones achievements of previous industries. The fourth industrial revolution comes with a bigger generalization of historical milestones of the industry, leveled into four stages (mechanization, electrification, digitalization, cyber-physical) (Drath & Horch 2014; Schwab 2016). This is similar with THIO concept, with four components and four stages on each component, technoware (manual, powered, automatic, programmable), humanware (operation, setting, adjusting, improvising), infoware (superficial, elementary, fundamental, frontier) and organware (impromptu, orderly, scientific, optimized) (Sharif 2009).

State of the Art of Technology-Driven Approach

The researchers have shown the historical momentums of the industry have a significant influence on the future stages of industrial milestones (Harms, Baetz & Volti 2004; McNeil 2002; Swamidass 2000; Wright 2001). By examining the history of industrial momentum, we can examine how innovations, quality, efficiency, and effectiveness are created by a journey of that momentums. Past research already synthesizes these momentums to develop the industrial maturity index. Below is the result of qualitative research involving experts and present industrial players in the press part automotive manufacturing industries in Indonesia (Afifi 2011b).



Industry 4.0	THIO		Industrial Maturity Index			
Mechanization	Stage 1		1. Manual		7. Data using	
Electrification	T	Manual	T	Basic tools	T	Robotic, multi purpose machine
Digitalization	H	Operation	H	Learn to know	H	Intermediate programmer
Cyberphysical	I	Superficial	I	Paper	I	Design standard
	O	Impromptu	O	Single main work range	O	Product (various) based, flexible manufacturing system
	Stage 2		2. Mechanization		8. Efficiency	
	T	Powered	T	Devices	T	Rapid prototyping, robotic material handling
	H	Setting	H	Technician	H	Advanced programmer
	I	Elementary	I	Paper files	I	Integrated system
	O	Orderly	O	Unique product	O	Taguchi, lean manufacturing
	Stage 3		3. Powered		9. IT Based	
	T	Automatic	T	Machine	T	Distributed control system
	H	Adjusting	H	Mechanic	H	Engineer
	I	Fundamental	I	Files sheet	I	System networking
	O	Scientific	O	Orderly manufacture	O	Supply chain, value chain, customer based
	Stage 4		4. Division of labor		10. Outsource	
	T	Programmable	T	Production assembly line	T	Interfacing technology
	H	Improvising	H	Assembler	H	Intermediate engineer
	I	Frontier	I	Manual instruction	I	Multi user system, cloud
	O	Optimized	O	Management by objective	O	Resizing structure, virtual organization
			5. Numerical Computation		11. E-Industries	
			T	PLC, computer numerical control	T	Monitoring technology
			H	Operator	H	Advanced engineer
			I	Standard operation procedures	I	Dynamic database
			O	Design calculating & analysis, scientific management	O	Dynamic structures, e-organization
			6. Effectiveness			
			T	Machine vision, inspection machine		
			H	Programmer		
			I	Standard quality control		
			O	TQM, kaizen, six sigma, advanced analysis		

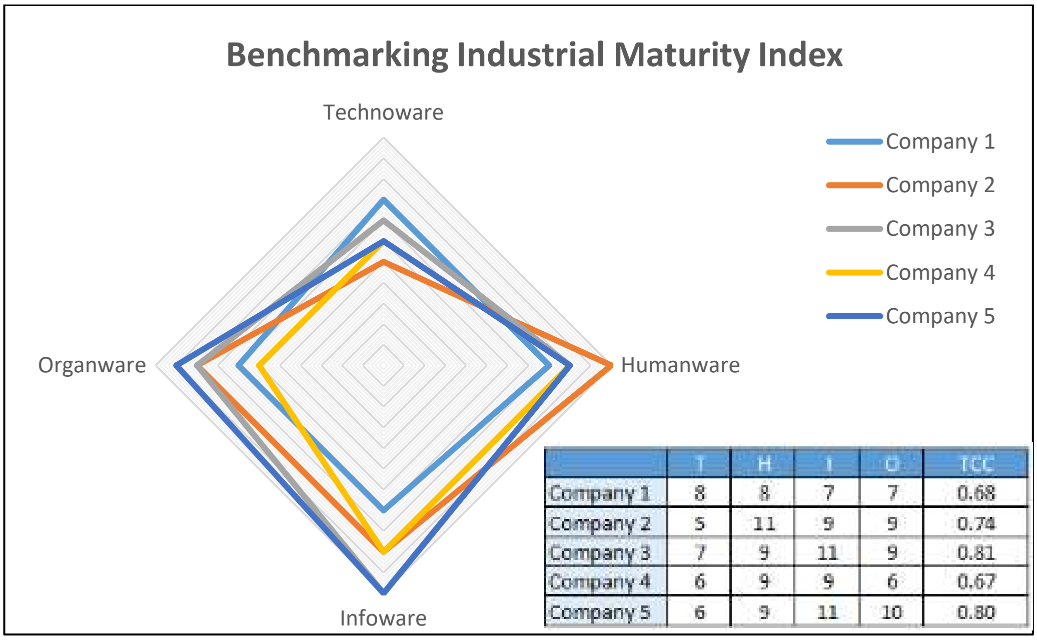
Table 1. State of the art of Industrial Maturity Index (Afifi 2011a), compared with Iustry 4.0 and THIO.

Dynamic of Technology-Driven Resources

Technology-driven resources components were interacting dynamically between each other in the industrial system, which means any component of technology-driven resources are influencing each other to reach their optimum condition and advanced to the next stage (Sharif & Ramanathan 1991). It makes sense if each of component technology-driven resources are not on the same initial stage in common circumstances, for example on industrial maturity model T on level 3, H on level 5, I on level 2 and O on level 4, even mostly by time each component interacts dynamic and influencing each other upwards or even downwards.

Dynamic changes and interaction of technology-driven resources will influence the industry strategy, shape their business model dynamically, and give impact to industry performance (Khodaei & Ortt 2019; Osterwalder et al. 2010; Teece 2018; Teece et al. 1997). Hence, we need the industrial maturity index to guide us to distinguish the dynamic changes and recognize the positive transformation of technology-driven resources components. As an example, when we observe manually and simplicity, two terms with the common perceptions, but technically both of them have a different approach, complexity, and values in practices. This is the reason we need this industrial maturity index as an indicator of our dynamic changes and interaction, whether it is in a positive direction to leverage our industrial maturity condition.

Transformation of changes need involvement in any level management and organization, and the main target of changes is not just to jump in to the next level by adjusting equipment or adapting new approach, simply by optimizing current condition until matured and developed using next level of approach (Sauser 2010; Schonberger 1986). By adapting to dynamics and changes, this will motivate industries to find the optimum condition and learn to leverage themselves to improve the industry. This is why the dynamic interaction of technology-driven resources needed by industries today is emerging as they need to become a learning organization (Hayes, Wheelwright & Clark 1988).



	T	H	I	O	TCC
Company 1	8	8	7	7	0.68
Company 2	5	11	9	9	0.74
Company 3	7	9	11	9	0.81
Company 4	6	9	9	6	0.67
Company 5	6	9	11	10	0.80

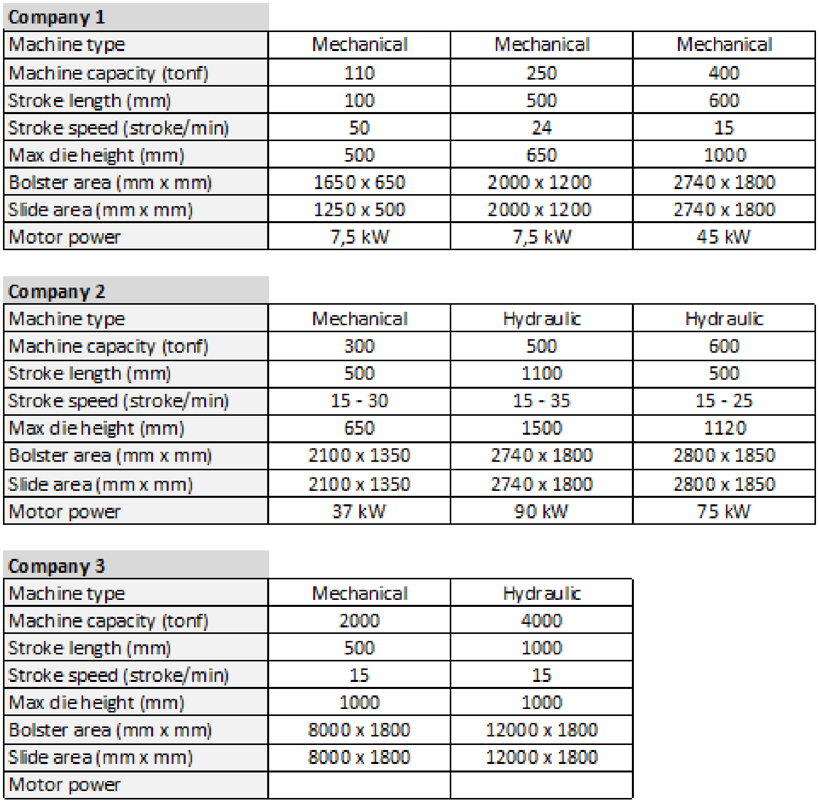
Figure 3. Benchmarking Industrial Maturity Index of Press-part Automotive Industry on radar diagram (Afifi 2011a)

Index Measurement and Techno-Metric

The Industrial maturity index will not complete when we cannot fill the information gap between our initial condition and conceptual ideas. How we can identify the industrial maturity around our group of industry and how we can identify industrial competitiveness between competitors. By adopting simple measurement techno-metric using technology contribution criteria (TCC) function of (T, H, I, O) (Sharif & Ramanathan 1991) tested in iron and steel industry (Ramanathan 1988), and with industrial maturity index values in automotive press part industries as shown in Figure 3 (Afifi 2011a).

$$TCC = \propto T^{\beta_t} . H^{\beta_h} . I^{\beta_i} . O^{\beta_o}$$

Where β_x is the coefficient of the importance of each component with $\sum\beta=1$, for simple measurement we can assume $\beta_x = 0.25$, which are equal in every component of technology, while α the technology climate factor. For standalone industry or analyzing one sector of industry we can assume $\alpha = 1$, and for advanced analysis of group of industry or multi sectors we can use $\sum\alpha = 1$. In industrial maturity development index measurement we use $\alpha = 0.091$, since it have 11 stages and as normalization to limit $TCC_{max} = 1$ (Afifi 2011a). Using this formula, we can make quantitative measurements for various industries group like (1) standalone industries, (2) industrial sectors, (3) group of industries or competitors, (4) regional Industries, etc.



Company 1			
Machine type	Mechanical	Mechanical	Mechanical
Machine capacity (tonf)	110	250	400
Stroke length (mm)	100	500	600
Stroke speed (stroke/min)	50	24	15
Max die height (mm)	500	650	1000
Bolster area (mm x mm)	1650 x 650	2000 x 1200	2740 x 1800
Slide area (mm x mm)	1250 x 500	2000 x 1200	2740 x 1800
Motor power	7,5 kW	7,5 kW	45 kW

Company 2			
Machine type	Mechanical	Hydraulic	Hydraulic
Machine capacity (tonf)	300	500	600
Stroke length (mm)	500	1100	500
Stroke speed (stroke/min)	15 - 30	15 - 35	15 - 25
Max die height (mm)	650	1500	1120
Bolster area (mm x mm)	2100 x 1350	2740 x 1800	2800 x 1850
Slide area (mm x mm)	2100 x 1350	2740 x 1800	2800 x 1850
Motor power	37 kW	90 kW	75 kW

Company 3		
Machine type	Mechanical	Hydraulic
Machine capacity (tonf)	2000	4000
Stroke length (mm)	500	1000
Stroke speed (stroke/min)	15	15
Max die height (mm)	1000	1000
Bolster area (mm x mm)	8000 x 1800	12000 x 1800
Slide area (mm x mm)	8000 x 1800	12000 x 1800
Motor power		

Table 2. Production Capability of Automotive Press-part Industry (Afifi 2011a)

Technical Capability and Product-Service Specification

As mention above about competitiveness, the market can be explained using product or service specification as an interpretation of customer needs that associate with technical specifications as production capability. Production capability is diverse in industries, some of it relies on one or more of component technology-driven resources. In this manufacturing case in the Automotive Press part Industries, it relies on its machine.

Table 2 provides some data of machines from various companies in Automotive press part Industries in Indonesia which taken in 2011. By identifying each machine's specifications in industries, we can recognize this industry capability. Machine capability defines what product material can be processed. From the data shown, we can classify that company 3 machines with big capacity and hydraulic type were mostly used for chassis production, while machines with medium capacity used for body parts, and small machine capacity for small parts.

CONCLUSION

The industrial maturity development index consist of two approaches; first is by identifying the industrial maturity index from technology-driven resources and second is by identifying production capability and associate it with product or services specification. The technical detail to identify and optimize each stage can be referenced to any studies related to a specific trend in each stage. This Industrial Maturity Development Index can be an alternative to see improvements and innovations with some scaled and stages of the transformation process.

These two approaches are linked to each other, while the development of the industrial maturity index persistently will give benefit to its production capability. Not like the industrial maturity index that can be generalized to many sectors of industries, production capability on the other side are specific by sectors of industries. More research needed on how each sector of industry identify their product or services specification, for an example in postage industry they use distance and weight of goods to correspond with customers. Future research for the industrial maturity index is wide open, from how to identify stages, make optimization on it and an exploration application to identify βx in each sector of industries and α for each sector of group multi sectors of industries.

REFERENCES

Acs, Z., & Varga, A. 2005. Entrepreneurship, agglomeration and technological change. *Small Business Economics* 24: 323–334.

Afifi, A. A. 2011a. Analisis kemampuan industri manufaktur otomotif Mengacu pada pola pengembangan teknologi (Universitas Indonesia). https://doi.org/10.13140 /RG.2.2. 16897.51045 [6 August 2018].

Afifi, A. A. 2011b. The Industrial Manufacturing Maturity Model (IM3) Based On State of the Arts of Technology Development. Proceeding of the 12th International Conference on QiR (Quality in Research). Bali: Universitas Indonesia.

Apriyani, Ika, S. R., & Sarnowo, H. 2019. Pengaruh Koneksi Politik Dan Corporate Governance Terhadap Manajemen Laba. *ISEI Economic Review*, 8–15.

Daft, R. L. 2010. *Organization Theory and Design*. https://books.google.com.my/books?id = CmFjF5tNmuEC [3 Sept 2019].

Departemen Perindustrian. 2008. Penguatan Inovasi dalam Perspektif Kebijakan Industri

Nasional. *Rakornas Ristek*.

DeSarbo, W. S., Benedetto, C. A. Di, Song, M., & Sinha, I. 2005. Revisiting the Miles and Snow strategic framework: uncovering interrelationships between strategic types, capabilities, environmental uncertainty, and firm performance. *Strategic Management Journal* 26(1): 47–74. https://doi.org/10.1002/smj.431[20 July 2019].

Drath, R., & Horch, A. 2014. Industrie 4.0: Hit or Hype? [Industry Forum]. *Industrial Electronics Magazine, IEEE*, *8*, 56–58. https://doi.org/10.1109/MIE.2014.2312079

Grant, R. 2003. Strategic Planning in a Turbulent Environment: Evidence from the Oil Majors. *Strategic Management Journal* 24: 491–517. https://doi.org/10.1002/smj.314 [12 May 2018].

Harms, A. A., Baetz, B. W., & Volti, R. 2004. *Engineering in Time: The Systematics of Engineering History and Its Contemporary Context*. Imperial College Press.

Hayes, R. H., Wheelwright, S. C., & Clark, K. B. 1988. *Dynamic Manufacturing: Creating the Learning Organization*. Free Press.

Indrajit, R. E., & Pramono, A. 2005. *Manajemen Manufaktur: Tinjauan Praktis Membangun & Mengelola Industri*. Pustaka Fahima.

Kementerian Perindustrian. 2015. Rencana induk Pembangunan Industri Nasional 2015 - 2035. 1–98. https://doi.org/10.1017/CBO9781107415324.004 [5 June 2018].

Khodaei, H., & Ortt, R. 2019. Capturing dynamics in business model frameworks. *Journal of Open Innovation: Technology, Market, and Complexity* *5*(1): 8. https://doi.org/10.3390/joitmc5010008 [5 June 2018].

McNeil, I. 2002. *An Encyclopedia of the History of Technology*. Taylor & Francis.

Okhmatovskiy, I. 2010. Performance implications of ties to the government and SOEs: A political embeddedness perspective. *Journal of Management Studies* 47(6): 1020–1047. https://doi.org/10.1111/j.1467-6486.2009.00881.x [8 May 2017].

Osterwalder, A., Pigneur, Y., Smith, A., & Movement, T. 2010. Business model generation. A handbook for visionaries, game changers, and challengers. https://doi.org/10.1523/JNEUROSCI.0307-10.2010 [26 February 2018].

Parnell, J., & Brady, M. (2019). Capabilities, strategies and firm performance in the United Kingdom. *Journal of Strategy and Management* 12(1): 153–172. https://doi.org/10.1108/JSMA-10-2018-0107 [26 February 2018].

Porter, M. E. 1980. *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. Free Press.

Porter, M. E. 1985. *Competitive Advantage: Creating and Sustaining Superior Performance*.

Ristekdikti. 2017. *Sistem Inovasi Nasional Untuk Mendukung Kemandirian dan Daya Saing*.

Sauser, B., Gove, R., Forbes, E., & Emmanuel Ramirez-Marquez, J. 2010. Integration maturity metrics: development of an integration readiness level. *Information Knowledge Systems Management* 9: 17–46.

Schonberger, R. 1986. *World Class Manufacturing: The Lessons of Simplicity Applied*. https://books.google.com.my/books?id=lidPAAAAMAAJ [2 June 2017].

Schwab, K. 2016. *The Fourth Industrial Revolution*. World Economic Forum.

Sharif, N. 2009. *Technology Planning and Technology Governance Meeting*. Myriad Solutions.

Sharif, N., & Ramanathan, K. 1991. Measuring Contribution of Technology for Policy Analysis. *Proceedings of the 1991 International System Dynamics Conference: System Dynamics* 91: 534.

Suarez-Villa, L. 1989. *The Evolution of Regional Economies: Entrepreneurship and Macroeconomic Change*. Praeger.

Swamidass, P. 2000. *Innovations in Competitive Manufacturing; from JIT to E-Business*.

Teece, D. J. 2018. Business models and dynamic capabilities. *Long Range Planning* 51(1): 40–49. https://doi.org/10.1016/j.lrp.2017.06.007

Teece, D. J., Pisano, G., & Shuen, A. 1997. Dynamic capabilities and strategic management. *Strategic Management Journal* 18(March) : 509–533.

Timings, R., & Tooley, M. 2001. *Basic Manufacturing*. T. Thompson (eds.). Newnes.

Ulrich, K. T., & Eppinger, S. D. 2008. Product Design and Development.

United Nations Industrial Development Organization. 2002. Annual Report 2002.

Wright, P. K. 2001. *21st Century Manufacturing*. Prentice Hall.